

# Annals of conflicting results: looking back on electromagnetic field research

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## Abstract • Résumé

Few environmental health issues are as contentious as the question of whether exposure to electromagnetic fields (EMFs) from power lines increases cancer risk. Among the many actors in this controversy, epidemiologists have played the leading role in raising the question and motivating research. Epidemiologic studies of the effects of exposure to power-line EMFs include the investigation by Dr. Gilles Thériault and colleagues into incidence rates of cancer among electric-utility workers in Quebec, Ontario and France. With the development of personal dosimeters to measure exposure to electric, magnetic and pulsed EMFs, occupational studies in the 1990s have made an important methodologic advance. But, as Thériault explains, improvements in assessing exposure have not yet translated into clear and consistent findings.

Peu de questions de santé liées à l'environnement sont aussi litigieuses que celle de savoir si l'exposition aux champs électromagnétiques des lignes de transmission augmente les risques de cancer. Parmi les nombreux intervenants dans cette controverse, les épidémiologistes ont joué le rôle de premier plan en soulevant la question et en catalysant les recherches. Les études épidémiologiques sur les effets de l'exposition aux champs électromagnétiques des lignes de transmission comprennent celle que le Dr Gilles Thériault et ses collègues ont effectuée sur les taux d'incidence du cancer chez les travailleurs des entreprises publiques d'électricité au Québec, en Ontario et en France. Avec la mise au point de dosimètres personnels qui mesurent l'exposition à des champs électriques, magnétiques et électromagnétiques pulsés, les études sur le travail effectuées au cours des années 90 ont réalisé d'importants progrès sur le plan de la méthodologie. Comme l'explique toutefois le Thériault, les améliorations de l'évaluation de l'exposition n'ont pas encore donné de résultats clairs et uniformes.

When Dr. Gilles Thériault presents his research on electromagnetic fields (EMFs) he begins with the question "Do you realize that we're going through a revolution, a big revolution? I call it a nonionizing energy revolution." The nonionizing energy is that of electromagnetic radiation at frequencies below those of x-rays and gamma rays. The revolution is the increasing array of devices — ranging from remote controls and cellular phones to specialized telecommunications and medical equipment — that contribute to what Thériault calls an "invisible landscape" of electromagnetic energy.

The next question Thériault asks concerns the effects of EMFs on human health. Can exposure to EMFs increase the risk of cancer? In the last 25 years this question has been asked repeatedly, primarily with respect to the extremely-low-frequency fields produced by 50-Hz and 60-Hz power lines. Figuring prominently in the epidemiologic research is Thériault's investigation of inci-

dence rates of cancer among electric-utility workers in Quebec, Ontario and France.

Thériault is not new to the field of occupational epidemiology. In 1970 he left general medicine to study industrial health at Harvard University. He received his doctorate from the School of Public Health at Harvard in 1973 and returned to Quebec, taking up research and teaching positions first at Laval University and then at McGill University. He is now chair of the Department of Occupational Health at McGill.

## The EMF debate

The general boundaries of the controversy over the public health implications of EMFs are well marked. On one side are those who believe that epidemiologic evidence of an association between EMFs and cancer justifies immediate action to protect the public. This view was popularized in the early 1990s by journalist Paul Brodeur in a series of *New Yorker* articles ("Annals of Radiation") and in his book, *The Great Power-Line Cover-up*.<sup>1,2</sup>

On the other side of the debate are those who regard

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the hypothesis as unsubstantiated conjecture that has led to a bad case of environmental phobia. Their arguments generally focus on what they view as the absence of a plausible mechanism by which extremely-low-frequency EMFs could affect living cells.

Dr. William R. Bennett, a physicist at Yale University, maintains that "the fields induced in the body from such sources [as power distribution lines and home appliances] must be small compared to unavoidable fields that are present all the time from natural processes. Fear of adverse health effects from power lines will go down in history as another case of nonscience."<sup>3</sup>

Individual epidemiologists and physicists vary greatly as to their position in this spectrum of opinion. Nonetheless, epidemiology, as a discipline, takes credit for having put the issue on the table and keeping it there.

## Residential exposure studies

Thériault's EMF work forms part of what he refers to as second-generation studies. The first generation arose in the mid-1970s with the work of Dr. Nancy Wertheimer at the University of Colorado. Wertheimer was interested in the possible environmental causes of cancer in children. Each time she received a report of childhood cancer in the greater Denver area she drove to the child's home and took note of various factors such as population density, traffic and other sources of pollution. It struck her that the homes she visited were "unduly often near electric lines carrying high currents."<sup>4</sup>

With physicist Ed Leeper, Wertheimer categorized the power lines near the children's homes into "wiring configurations" according to the current carried, the number of wires and the distance of the lines from the

homes. This classification system constituted a surrogate measure of exposure to magnetic fields. Wertheimer and Leeper did not consider electric fields, noting that magnetic fields rather than electric fields readily penetrate buildings and the human body.

Comparing the wiring configurations near the homes of children who had died of cancer with those near the homes of matched controls, Wertheimer found a statistically significant association between childhood cancer and configurations that would be expected to result in stronger magnetic fields. She suggested that the fields produced by wire currents could result in a greater risk of cancer, although she did not consider the increase, two- to three-fold at most, to be very high. For the first time the question of carcinogenic effects from EMFs had been raised.

"It was a shock when she published this in 1979," says Thériault. "People said there was not enough energy in the wires to be associated with leukemia, so they didn't believe her. They thought she had made a mistake somewhere. But nobody has been able to reject what she observed, nobody."

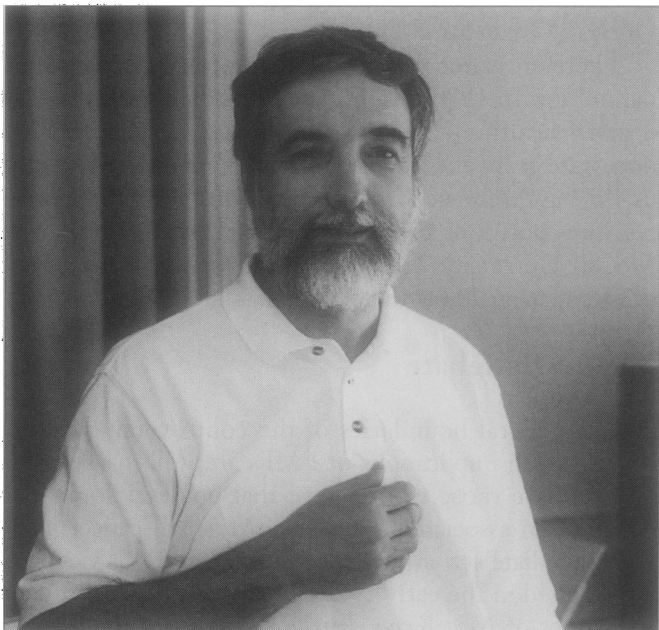
Further studies conducted in the United States<sup>5,6</sup> and Sweden<sup>7</sup> obtained similar results, although one study conducted in Rhode Island showed no association between wiring configuration and childhood cancer.<sup>8</sup> The positive findings were obtained only when wiring configuration was used as the basis for assessing exposure; when EMFs were measured directly inside the homes, the association between EMF exposure and cancer disappeared.<sup>5-7</sup>

This discrepancy may indicate that the presence of power lines is not the real cause of the increased risk for cancer but, rather, a characteristic associated with the true, as yet unidentified, causal factor. On the other hand, as Thériault suggests, it may mean that wiring configuration gives a better estimate of long-term exposure to EMFs than do short-term measurements, which are subject to considerable fluctuation.

## Occupational studies

By the late 1980s at least 14 retrospective studies had investigated the incidence of leukemia or brain cancer among workers whose exposure to EMF was believed to be elevated; most of these studies showed an increased risk among electric-utility, transportation and communications workers, electricians and electrical engineers.<sup>9</sup> On the other hand, several prospective studies showed little excess risk among broadly defined cohorts of electrical workers. However, more recent analyses of the prospective studies, in which the workers were regrouped to better reflect level of EMF exposure, found "many more significant excesses of leukaemia and brain cancer."<sup>9</sup>

Although the occupational studies of the 1980s were reasonably large, their exposure assessment, according to Thériault, was imprecise. For epidemiologists, assessing



**Dr. Gilles Thériault: Unperturbed by mixed results of epidemiologic research into electromagnetic fields.**

individual exposure accurately and in a way that targets critical periods in the development of a disease is crucial to sorting out indirect associations from true cause-and-effect. This is where the second-generation research comes in.

"There was a need in 1990 to have good, solid, comprehensive studies that would improve significantly on assessing exposure," says Thériault. "So at the start of our study we worked with engineers, and they designed a meter, a beautiful tool, that could measure . . . electric field, magnetic field, and a third dimension, pulsed electromagnetic field, thus giving a profile of exposure for the period of observation." Also called high-frequency transient fields, pulsed EMFs are very fast-changing fields generated during certain switching operations.

Thériault's study was retrospective: his research team identified 4151 cases of cancer that occurred from 1970 to 1989 among more than 223 000 utility workers in Quebec, Ontario and France and matched them with control subjects who worked at the same utility during that period. The cancers studied were of two categories: those for which a link with EMF had been suggested in earlier research — leukemia, brain cancer and melanoma — and all other cancers. For the first category, the case-control ratio was 1:4; for the second, 1:1.<sup>10</sup>

To estimate past exposure to electric, magnetic and pulsed electromagnetic fields, over 2000 current employees wore personal dosimeters for 2 weeks and kept a log of work activities and conditions. "We set up an expert panel of engineers and former employees and went through what the people were doing today in the different job categories," explains Thériault. "We asked if this is what they were doing 5, 10 and 15 years ago and used information on the power that was produced and sold in the past. We then put in the correcting factors for past exposure. But it's not easy to do. In the end we found that, for the man that does job X, his exposure of 15 years ago is just slightly different from today."

Along with Thériault's investigation, the second-generation studies included two large-scale retrospective studies in the United States<sup>11,12</sup> and one in Sweden.<sup>13</sup> These studies also used personal dosimeters to assess exposure to magnetic fields and controlled for known confounders, smoking habits and socioeconomic status. They also focused on the most suspicious cancers: leukemia, brain cancer and melanoma.

Research into EMFs appeared to be at a turning point. With improved exposure data, large populations and four independent studies on the people most exposed to EMFs, confirmation or refutation of an association between EMFs and cancer appeared to be within reach. Once again, however, the results were ambiguous.

The Swedish study<sup>13</sup> found a statistically significant dose-response relation between magnetic-field exposure and chronic lymphocytic leukemia. Thériault's study,<sup>10</sup> on the other hand, showed a significant association for

acute nonlymphoid and acute myeloid leukemia, but not for chronic lymphocytic leukemia. Moreover, there was no dose-response relation for the positive associations that Thériault found, and results were inconsistent across the three utilities studied.

The findings from the first US study, conducted in southern California,<sup>11</sup> were negative for all types of cancer examined. The second US investigation, which involved utilities in two southeastern states and in northern California,<sup>12</sup> indicated a statistically significant association with brain cancer but not with leukemia.

Where statistically significant associations were found in the four occupational studies, the incidence rate of cancer in the high-exposure group was generally two to three times the incidence rate in the low-exposure group. Yet the inconsistency of results precluded the interpretation of these values as estimates of the real increased risk for workers with high exposure.

Explaining his results to the public, Thériault says, "was tough to do. I felt it was my duty not to create panic, but I could not hide what I saw either. I had to say there might be a risk here. But it's minimal. And still, it belongs to the researcher's desk."

Explaining his results to physicists has perhaps been even more difficult. "I think physicists particularly should try to understand epidemiologists instead of taking the stance that there is nothing," says Thériault. "We're not saying that it is exactly the magnetic fields [from the power lines] that cause cancer. We are saying we have observed this association over and over, there must be something somewhere. Let us try to understand it. But . . . there is a war here between two disciplines."

## Other channels of the dosimeter

Working with Dr. Benedict Armstrong of the Department of Occupational Health at McGill and other collaborators, Thériault analysed the data from the Quebec and France cohorts of the tri-utility study together with data on exposure to pulsed EMFs.<sup>14</sup> Extremely-low-frequency pulsed EMFs were of interest because their biologic effects, such as effects on DNA synthesis in mammalian cells in vitro and changes in the secretion of melatonin in lab animals, had previously been observed.<sup>15,16</sup> Also intriguing was the long-standing therapeutic use of pulsed EMFs to promote bone regeneration.<sup>17</sup>

Again, results were puzzling. No association was found with leukemia, brain cancer or melanoma, but a strong association with lung cancer, showing a dose-response relation, turned up in the Quebec cohort. This association did not appear to be attributable to smoking habits or other confounders.

Thériault, Armstrong and their collaborators interpreted these findings cautiously. They had designed their study around the suspect cancers and considered the analysis for 13 other types of cancers to be ex-

ploratory. Moreover, the reliability of the pulsed-EMF measurements was questioned when it was discovered that the meters responded to a wider range of frequencies than had been realized. Nevertheless, although the "association between lung cancer and pulsed EMF exposure was an unexpected observation . . . it was very strong," Thériault notes. "Since then I have been saying on many occasions that this should be investigated further."

To date, analysis of electric-field data has been published only on the basis of the Ontario Hydro cohort of the tri-utility study. Dr. Anthony Miller of the Department of Preventive Medicine and Biostatistics at the University of Toronto and his colleagues carried out an independent examination of both electric- and magnetic-field data for the 31 543 Ontario Hydro workers.<sup>18</sup> Their analysis confirmed the positive associations that Thériault had found between magnetic-field exposure and certain types of leukemia, and also showed a positive association, with a dose-response relation, between cumulative electric-field exposure and the occurrence of leukemia.

Miller and his coauthors advise caution in interpreting these findings, as the original study was designed on the basis of the statistical power provided by inclusion of workers from the three utilities. They argue, however, that their analysis of the Ontario data improved on the assessment of exposure to electric and magnetic fields by taking into account job site as well as the nature of the work.<sup>18</sup>

## In search of the right question

"Something is going on that still evades our comprehension," Thériault concluded in a review of EMF research.<sup>9</sup> He remains optimistic, however, that the issue of EMFs and cancer will be sorted out in time. The breakthrough, he believes, will come by "asking the right question." He adds, "Wertheimer saw wire around the houses and she deduced that the problem was the magnetic field. I think we made a big jump without taking the time to think about it. The right hypothesis is something else."

What is the right hypothesis? Thériault believes that research on pulsed EMFs is on the right track. Another lead comes from investigations into the effect of relative orientation of applied extremely-low-frequency alternating-current magnetic fields and the earth's direct-current magnetic field on the release of calcium ions from cell tissues.<sup>19</sup> Other studies have explored the effects of extremely-low-frequency magnetic fields on gene expression in human cancer cells,<sup>20</sup> and there is a substantial body of research, also fraught with discrepancies, on the effects of extremely-low-frequency magnetic fields on the production of melatonin.<sup>21</sup> In a different vein, British physicists recently reported that electric

fields attract carcinogenic radon-decay particles.<sup>22</sup>

Eventually, such investigations may lead to the identification of specific characteristics of EMFs that play a role in the development of cancer. At that point epidemiologists can refine their measures of exposure and perhaps explain why the evidence on a possible link between EMFs and cancer has been contradictory. Meanwhile, Thériault is unperturbed by the mixed results of epidemiologic studies. "It's a new field of research," he says. "We must realize that, prior to 1979, almost nothing had been done with respect to electromagnetic fields from power lines and their potential for contributing to cancer. I think we have clues now that there is a problem."

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